

Space-time structure of climate variability

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The spatial scale of climate variability is closely linked to the temporal scale. Whereas fast variations such as weather are regional, glacial-interglacial cycles appear to be globally coherent. Quantifying the relationship between local and large-scale climate variations is essential for mapping the extent of past climate changes. Larger spatial scales of climate variations on longer time scales are expected if one views the atmosphere and oceans as primarily diffusive with respect to heat. On the other hand, the interaction of a dynamical system with spatially variable boundary conditions – for example: topography, gradients in insolation, and variations in rotational effects – will lead to spatially heterogeneous structures that are largely independent of time scale. It has been argued that the increase in spatial scales continues across all time scales, but up to now, the space-time structure of variations beyond the decadal scale is basically unexplored.

Here, we show first attempts to estimate and interpret the spatial extent of temperature changes at up to millennial time-scales, using instrumental observations, paleoclimate archives and climate model simulations. Although instrumental and climate model data show an increase in spatial scale towards slower variations, paleo-proxy data, if interpreted as temperature signals, lead to ambiguous results. An analysis of a global reconstruction of the last 10000 years (Holocene), for example, suggests a jump towards more localized patterns when leaving the instrumental time scale. Localization contradicts physical expectations and may instead reflect the presence of various types of noise. We further discuss the potential to separate externally forced climate signals from internal variability, by their respective and potentially different space-time structure. Ultimately, more complete knowledge of space-time scaling should improve physical understanding of climate variability and allow for better use of the paleoclimate record to map past variations.

[1] Laepple & Huybers, PNAS **111**, 16682 (2014).

[2] Laepple & Huybers, GRL GL059345 (2014).

[3] Mitchell et al., QSR **6**, 481 (1976).